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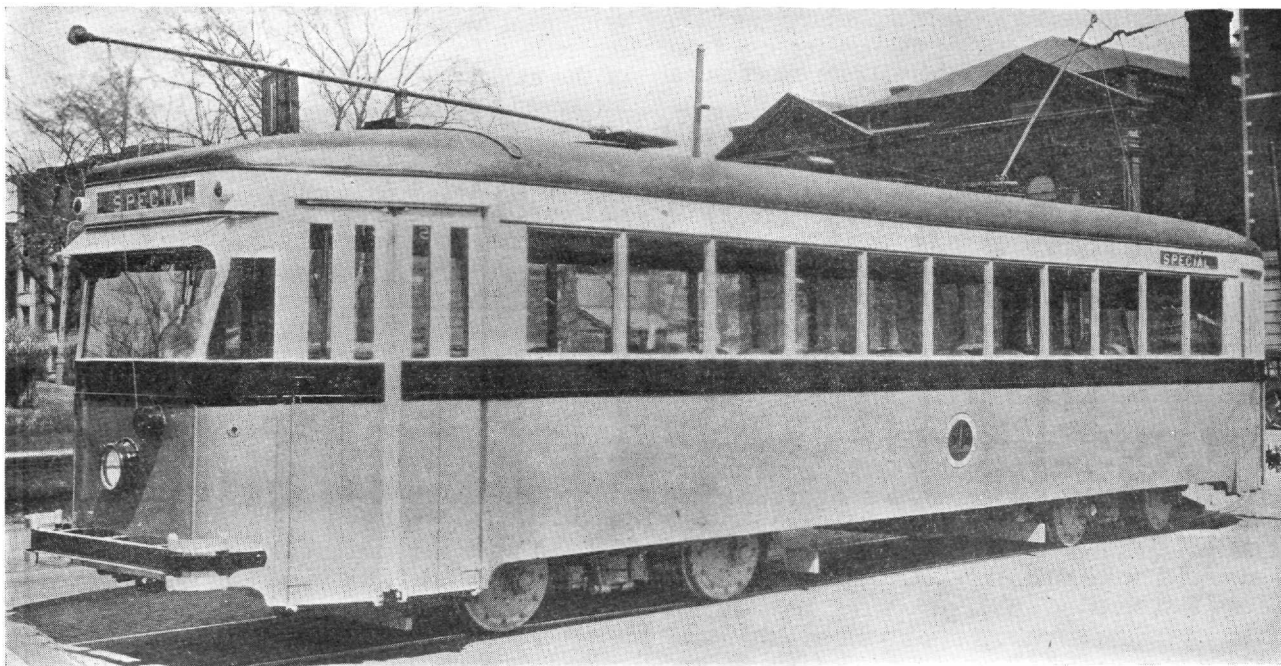
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Modern Tendencies in Surface Transportation

By L. P. DOYLE, '27



The Original Worm-drive City Car, Springfield (Mass.) Street Railway

EDITOR'S NOTE

Mr. Doyle is now a general engineer with the Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa. He assisted in installing the new worm drive street cars with automatic acceleration and automatic dynamic braking for the United Railways and Electric Company at Baltimore, Maryland.

The general trend in street railway operation is towards higher acceleration rates and schedule speeds, combined with comfort and safety. Surface transportation requirements have undergone numerous changes during the past decade. In the very early days of street cars, ideal performance was achieved by having more power and more speed than other vehicles, which were, of course, horse drawn. Then gradually the size, speed, and power of the cars increased in later designs and the ideal represented something better than previously. Soon automobiles began to appear but without difficulty the street car remained the fastest vehicle on the street.

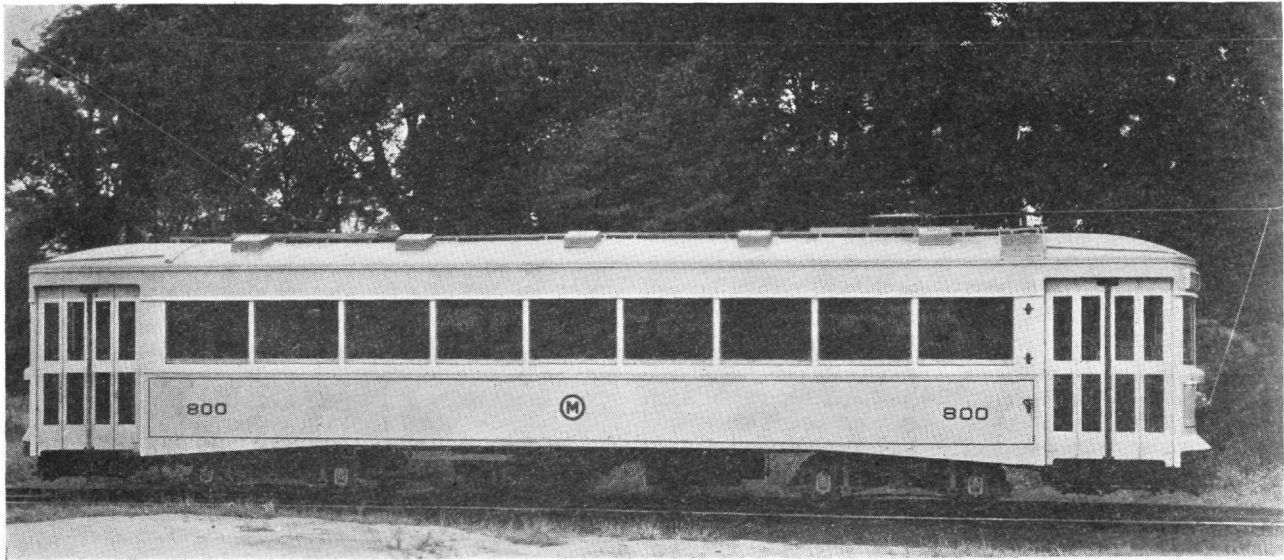
The next stage, however, found the automobile developing at a faster rate than the street car. The period of the war brought about an accelerated development of automobiles for the needs of the war. At the same time the street railway progress was slowed down to a virtual standstill. It was here that the automobile secured a running start and began to pass the street car in transportation performance and speed. The automobile, though starting later, moved forward with a greater rate of progress so that it crowded the street car back among the slower forms of traffic. However, the street railway operators have not been content to remain at the end of the traffic line and have been fighting hard to regain their leadership in the surface transportation field.

Out of the "din of the battle" came some revolutionary ideas in street-car design—methods of operation and drive. Perhaps the biggest factors in assisting the street railways to catch up with the march of progress are the modern high speed motors, the methods of drive, and control. The last year has witnessed the advent of the worm drive with differential axle and a much higher speed motor, and the double reduction gear in the form of a separate gear unit—the WN drive—which permits of even higher armature speed. The modern motor with single reduction gear and low wheels has about the same armature speed as that of the old double reduction motors so that the latest double reduction gives an unprecedented speed for street railway motors.

MOTOR

The most interesting feature of the modern high speed motors for use with WN and worm drive, is that they are designed to operate two motors in series on 600 volts, that is, with 300 volts per commutator. For this type of service the 300 volt motor is preferable for the reasons hereinafter explained, but when properly designed the 600 volt motor will give satisfactory service. The 300 volt motor provides greater margins of safety, and consequently can perform in more severe service for a given rating.

The mechanical construction of the armature is improved. Since the voltage across each motor is halved, the number of conductors in the armature can be decreased with a corresponding increase in the size of the wire. A stronger construction is obtained which materially reduces the motor failures due to lead breakage. Fewer conductors



Light Weight City Car, Parkersburg, W. Va.

reduce the space required for insulation, allowing more copper to be used in the same size slots, and with larger wire, stronger insulation can be obtained.

The tendency of a motor to flash depends, to a large extent, upon the voltage between commutator bars which must be short-circuited by the brushes. The commutators on a 300-volt motor will have nearly as many bars as a 600-volt motor, consequently the short circuit voltage per brush will be nearly halved. This will reduce the flashing to a negligible amount. During braking, when the voltage on the motors may rise above the trolley voltage, the motors will still have a greater margin of safety in respect to short circuit brush voltages than the present 600-volt motors without braking.

Why have 300-volt motors not been used before? The larger motors can be designed satisfactorily for 600-volt service without any great difficulty. Until the past few years there has always been a demand for two-motor equipments in the smaller size motors, so that it was always necessary to have a 600-volt motor for this service in order to

reduce resistance losses. The modern tendency is largely to the use of four-motor equipment. Under these conditions, the use of a 300-volt motor offers no difficulties.

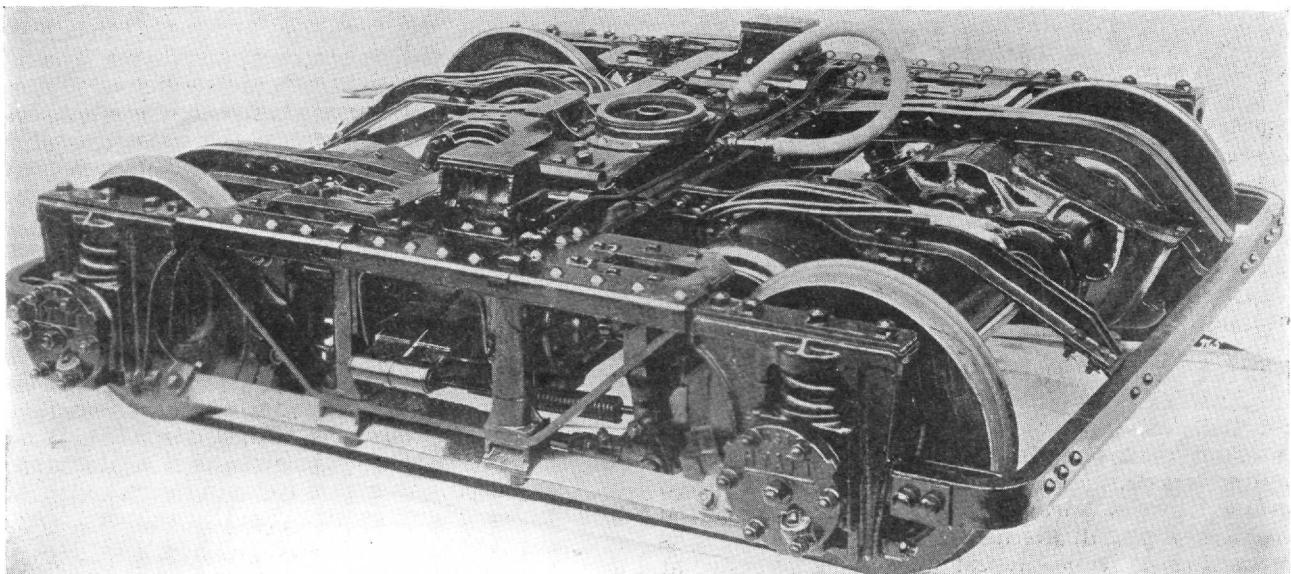
The objection has been raised that wheel slippage will cause trouble. The answer is that almost all 1500 and 1200 volt equipments have two motors in series at all times. Wheel slippage on these cars is never a serious problem.

One important feature which goes far to make the high speed motor a success is the fact that the motor is entirely spring suspended. This greatly reduces the effect of road shocks on the motor.

MODERN AUTOMATIC CONTROL

Automatic control has been used on street cars for the last fifteen or twenty years. This control in nearly all cases was patterned after the automatic control used so successfully today on rapid transit lines. The operating conditions for surface cars are very different from those of the rapid transit car, and consequently the older type of

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Typical Truck Assembly of WN Drive and High Speed Motors

SURFACE TRANSPORTATION

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automatic control for surface cars did not meet the requirements with sufficient success to give it any great popularity. The control requirements on a modern surface car are very different from those of a few years ago. Operating conditions are different and the street car today must operate under widely varying conditions. In the congested areas all vehicles are operating as closely together as is mechanically possible, requiring very slow acceleration and movement of traffic. In this area it is highly desirable that all vehicles accelerate rapidly in order that the maximum number may pass on the "go" signal of the traffic lights. High rates of acceleration are also desirable in the non-congested districts as an aid to increased schedule speeds.

Variable traction conditions are present as well as variable traffic conditions. The available traction on a line may vary over a wide range during a one-way trip of a street car, this variation depending on the amount of automotive traffic over the rail, type of paving, open rail, weather conditions, grades and many other factors. Also the tendency today is to decrease car weight and increase motor capacity. There will, therefore, be a greater change in the total weight from no load to a fully loaded car. To obtain maximum efficiency of car performance, the control of the car must compensate for this rather severe change.

To meet the variable traction and traffic conditions the variable automatic type of control has been designed. Acceleration is automatic and controlled by the master controller. Variable tractive effort is obtained by having a series of positions on the master controller which correspond to predetermined accelerating rates. A current limit relay is used to govern the rate of acceleration.

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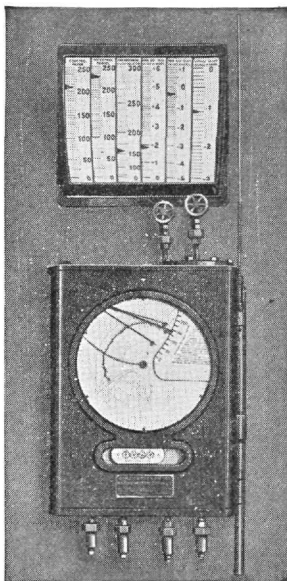
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SURFACE TRANSPORTATION

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This relay has a shunt coil on it which is used in connection with the master controller. The position of the master controller determines the amount of resistance in series with the coil. Changing the current flow through the shunt coil by manipulation of the master controller determines the setting of the relay. The rate of acceleration is proportional to the deflection of the controller handle or accelerator pedal. Variable tractive effort is necessary for several reasons. The operator must accelerate slowly in very dense traffic and rapidly when the streets are clear. It is essential to keep the rates of acceleration when the load and grade increases, particularly during rush hours.

DYNAMIC BRAKING

A moving car has a certain amount of kinetic energy which is proportional to the square of its speed. In bringing the car to a stop, this energy must be dissipated. This can be accomplished either by the use of friction brakes or by driving the motors as generators. In the latter case, the power recovered may be put to useful work. Theoretically the power thus obtained may be used in two ways. It can be returned to the trolley wire or used for heating the cars. With the present development of the art the former is not feasible on a street car because of the excessive amount of apparatus involved. The second has been and can be accomplished in a satisfactory and economical manner by placing the motor resistors inside the cars and using them for a load.

A series motor, when driven by an external force, will act as a generator if the fields are reversed in respect to the armature. The voltage obtained from an electric generator is proportional to the field strength and the speed. In a series generator the field is excited by the load current, so that the greater the load current the higher the voltage.

In many ways, the motors are subjected to more severe service when used during braking than when propelling the car. This is principally due to the greater voltages and currents obtained at the higher speeds. When accelerating, the current in the motor decreases with speed, so that heavy loads are never encountered with high speeds. Also the voltage is limited. When braking, the maximum current is obtained at all speeds and the voltage may be greater than when motoring. This feature requires that special considerations be taken in the design to assure the same margins of safety which can best be obtained with 300-volt motors, two permanently connected in series.

When braking is applied, the motors, acting as generators, feed into the resistors. For any given car speed the voltage and current depend upon the amount of resistance placed in the circuit. The current originally flowing produces a retarding effort which reduces the speed and voltage, and with the reduced voltage the retarding effort decreases. The effect is cumulative so that the retarding effort will rapidly decrease unless the resistance is reduced with the speed. With the automatic control, the resistors are cut out by means of a current relay which so manipulates the control

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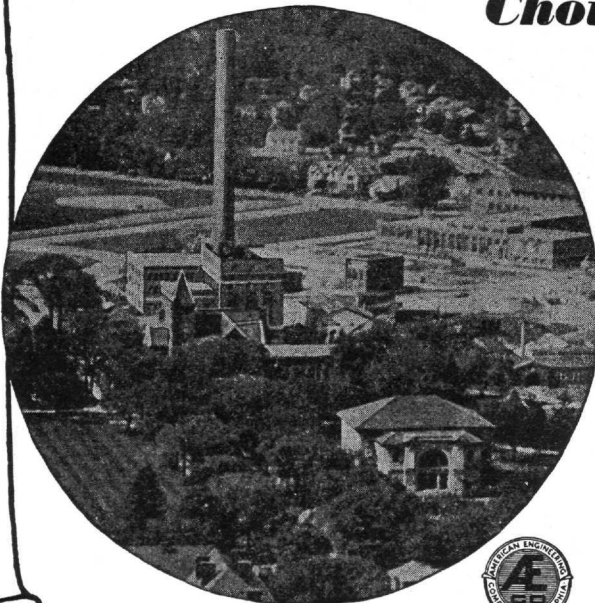
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SURFACE TRANSPORTATION

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that a nearly constant current is maintained down to about 3.00 m. p. h. at which time the air is applied for a complete stop. On a car there are two or more series motors in parallel, acting as generators, supplying power to a single resistor. This combination is unstable as one generator will assume more than its share of the load and tend to drive the others as motors. To make the combination stable, the field of one motor must be connected in series with the armature of the next motor. For service dynamic braking, time is conserved by not waiting for the residual flux to act, but by separately exciting one motor field causing instantaneous pick-up of the braking load.

Besides the power savings in using dynamic braking losses for car heating, there are several other important advantages of dynamic braking. An additional safety factor is provided in stopping without resorting to the usual destructive method of bucking the motors. Dynamic braking also reduces the wear on wheels, brake shoes and brake rigging.

The trend is, therefore, towards modernization of surface car equipment, as is evidenced by recent large orders of modern street-car equipments. The street car today is operating in a highly competitive field—with the modern busses and private automobiles. With the modern equipped street car, higher accelerating rates and running speeds can be accomplished with passenger comfort comparable with that of the latest model automobile.



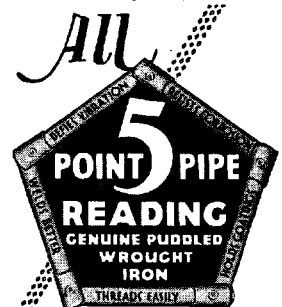
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